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A Standards-based Modelling Approach for Dynamic Generation of Adaptive Learning Scenarios

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Abstract: One of the key problems in developing standard based adaptive courses is the complexity involved in the design phase, especially when establishing the hooks for the dynamic modelling to be performed at runtime. This is particularly critical when the courses are based on adaptation-oriented learning scenarios, where the full eLearning cycle (design, publication, use and auditing) is considered. Based on the problems we experienced in developing such scenarios with a reusable, platform independent, objective-based approach in the aLFanet project we have established an alternative framework in the ADAPTAPlan project, which focuses on dynamically generating learning design templates with the support of user modelling, planning and machine learning techniques. In particular, in this paper we describe the problems we are tackling and how we are relaxing the design work by automatically building the IMS learning design of the course from a simplified set of data required from the course authors.

Keywords: Metadata and Learning, Learning Objects, Learning Activities, Learning Design, Semantic Web, Pedagogy guidelines, Educational standards, Design templates, Adaptive eLearning, User Modelling
Categories: H.3.5, H.4.2, H.5.4, J.7

1 Introduction

One of the more challenging tasks in developing the personalised learning paradigm is the authoring task. It has been the major bottleneck for decades, from the ad-hoc approach of traditional ITS to the current management of educational standards. However the development of adaptive learning systems has undergone considerable change over the last years. Initially there were research prototypes for developing adaptive learning environments but more recent efforts are focussed on providing general solutions focussed on extending existing educational standards to support adaptive course delivery addressing students' individual needs [Paramythis, 04]. In this respect, there have been two types of approaches. On one side there are those that provide intelligent solutions to cover different issues such as: intelligent testing [Guzman, 07], capturing and analyzing student actions to create collaborative tutors [Harrer, 06], rule-based adaptation with selection of stability [De Bra, 06], authoring of adaptive hyperbooks [Murray, 03], re-using educational activities through distributed servers [Brusilovsky, 04a], dynamic course generation through AI planning techniques [Brusilovsky, 03], etc. Furthermore, there have been several reviews that cover existing approaches [Brusilovsky, 03; Brusilovsky, 99; Cristea, 04; Brusilovsky, 04b]. On the other side, an alternative line of development is to incorporate, through the usage of educational specifications and standards (IMS, SCORM), adaptive processes into modern large-scale web based education, where current Learning Management Systems (LMS) are applied [Baldoni, 04; Boticario, 06].

All these developments are coping with a critical issue, which is to manage all the possible situations that may arise during the course execution, taking into account the diversity of learning materials, pedagogical models, learning styles and learning needs considered in the user model. Current educational specifications and standards (e.g., IMS family) assume that there is an ideal design scenario, where all required elements can be managed in the design time, or in highly-requested adaptive scenarios, some features can be integrated with runtime adaptations (e.g. dynamic grouping, adaptive information filtering and retrieval) as long as the adaptations are pre-defined at design time [Burgos, 06]. However, not everything can be specified in advance by the author because unexpected situations appear at runtime that cannot be predicted at design time [Zarraonandia, 06]. Furthermore, even knowing everything in advance does not suffice because of the management problems involved, i.e., describing all the existing possibilities and making the adaptation process sustainable over time. To tackle this open issue, our first approach was to set up a step-wise design process to support adaptive course delivery in an open LMS based on standards [Santos, 04a; Santos, 06]. Our experience shows that the design phase is experienced as a complex task, especially when the pedagogical requirements in the course flow can be affected by runtime adaptations [Boticario, 07a].

In the paper we briefly summarize the authoring approach implemented in aLFanet (widely disseminated in several fora) and present the on-going works in ADAPTAPlan, where we explore an alternative approach based on our previous experience in developing adaptive scenarios within current LMS. The ADAPTAPlan approach focuses on providing dynamic assistance to support the author in developing and modelling learning design tasks. The present proposal differs from other related course generation approaches based on planning [Brusilovsky, 03; Ulrich, 05] and asks the authors to focus on those elements that require their experience and expertise.

This paper extends [Boticario, 07b] -where the ADAPTAPlan approach was introduced- with further details and the results achieved up to now. First, we summarize the results obtained in the aLFanet project with respect to the authoring process as the basis upon which ADAPTAPlan derives. Second, we describe the standards-based modelling in terms of the user features and the device capabilities. Third, we present practical considerations regarding the applicability of the approach. Fourth, we describe how dynamic modelling can also benefit from this design to provide a contextual support at runtime. Finally, we present on-going experiments that focus on validating this approach.

2 aLFanet approach

The aLFanet project aimed at providing adaptive course delivery based on pervasive use of standards and several user modelling techniques in a multi-agent architecture

[Van Rosmalen, 05]. In particular, standards from the IMS Global Learning Consortium[1]: IMS Metadata (IMS-MD), IMS Learning Design (IMS-LD), IMS Content Packaging (IMS-CP), IMS Question and Test Interoperability (IMS-QTI) and IMS Learner Information Package (IMS-LIP).

Because adaptation is not an idea that can be plugged into a learning environment or into a particular component, but a process that influences the full life cycle of learning, aLFanet took into account a complex process of four interrelated steps: (1) design of the learning experience (based on objectives, learning activities, user profile and services), (2) administration (i.e., management of all data including users' roles, access rights and services configuration), (3) usage (i.e., actual use of designed activities on the learning environment within the class context), and (4) auditing (i.e., authors get reports on the actual use of course design, namely descriptions on how users have performed on learning activities, in order to adjust course design). In aLFanet the four steps can be formulated as learner driven tasks thanks to the combination of learning design and runtime adaptations [Boticario, 07b].

At design time, alternative learning paths (pedagogical models described in terms of IMS-LD) can be pre-coded for different types of users. The design created in IMS-LD contains the logic for the pre-designed adaptations and provides the hooks and the information upon which the runtime adaptation bases its reasoning. At runtime, the system adds two dynamic pedagogical situations to the former design adaptations that are recurrent in online courses and that can be detected from users' interactions: students with a lack of knowledge and students with high interest level. To this aLFanet builds on a system architecture described elsewhere [Santos, 05], which consists of a decoupled set of independent open source components available under the GNU GPL license: aLFanet LD and QTI Authoring Tools, Coppercore LD engine, aLFanet adaptive and interaction packages under the OpenACS/dotLRN community.

aLFanet has been evaluated at four different pilot sites and both strengths and weak points were detected [Boticario, 07a]. The most telling issue from the evaluation was that authors experienced the design phase as a very complicated task for two reasons: (i) the wide variety of elements to be described and the difficulties in controlling their interactions to successfully orchestrate an adaptive course work flow, and (ii) the state of development of the authoring tools themselves, which consisted of a QTI authoring tool to control adaptive features of questionnaires through the usage of metadata and a LD authoring tool for the specification of the learning design. Although several features were included in those tools, following the suggestions from the first evaluation in pilot sites (e.g., a dynamic tree generation for visualising a course tree), these features were not sufficient to deal with the complexity of the process for non-expert authors.

To lessen the workload of the authoring process we defined a four-step methodology that utilised design templates, which are widely accepted as a required support in the instructional design arena [Leshin, 92]. First, course materials were developed as a set of learning objects. Second, metadata were added to those learning objects in order to be properly used in the course. Third, instructional design (pedagogical support) guided by learning objectives was defined. Finally, the fourth

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[1] IMS Global Learning Consortium: http://www.imsglobal.org/

step was to build an adaptive scenario for the course, which allows delivering the course, adapted to the individual learner needs, from the combination of design and runtime adaptations. The latter step is crucial to support the required adaptations provided at runtime. Its construction process consists of a sequence of steps with increasing levels of detail and possibilities for adaptation (differential, material and situated analysis), and it is described elsewhere [Santos, 06].

An important issue related to the aLFanet approach and the authoring problems detected is that this project represented an early adopter of educational standards (it started in the year 2002 when IMS-LD did not exist and its predecessor EML was our initial option), and therefore we had to develop our own architecture and authoring tools to support the full life cycle of learning and the adaptive features [Boticario, 07a]. Currently, some of those features are included in the open source OpenACS/dotLRN architecture, which we are using not only to manage the collaborative work of aDeNu research projects, but to support the research developments. The main advantages of using dotLRN LMS are 1) support for a wide range of educational standards (SCORM, IMS), 2) support for web services and 3) the accessibility of the provided services [Santos, 07a].

3 ADAPTAPlan approach

To tackle the aforementioned difficulties found in developing and modelling standards-based adaptive scenarios for current LMS we are exploring an alternative approach to provide dynamic assistance to authors, with the aim of helping them focus on those elements that require their experience and expertise. The ADAPTAPlan approach draws on utilising user modelling, planning and machine learning techniques to lessen the workload of the design phase in the previously described development of standards-based adaptive scenarios in current LMSs.

The general idea is to direct authors' attention to those elements they are used to manage and control in learning scenarios, like the specification of learning activities, temporal restrictions, evaluations, and not so much on a thorough description of alternative learning routes for different types of learners according to their features (i.e., learning styles, cognitive modalities, interest level, preferences…), which in any case are strongly dependent on learners' interactions and their evolution over time.

We differ from other course generation approaches in various ways. First, our approach relies heavily on a pervasive use of educational standards in current LMSs [Santos, 07a]. Therefore it is different to other ITS sequencing approaches that provide alternative descriptions for small-scale web-based education and research level systems [Brusilovsky, 03]. In particular we utilise IMS-LD as the top level driver of course workflows. This entails that authoring is supported by a high level specification to describe the teaching and learning process that is to be uploaded in standards-compliant LMS. Authors can describe roles, activities, basic information structure, communication among different roles and users; and all these using a pedagogical approach [Burgos, 06]. Furthermore, in IMS-LD the structure of the learning scenario is separated from the learning materials and services. Materials can then be reused within different scenarios. The scenarios can also be reused and new materials added. But first and foremost the driving force behind this approach is that through the IMS-LD specification authors have access to describing and implementing learning activities based on different pedagogies [Koper, 05], including group work and collaborative learning [Bote-Lorenzo, 04]. Therefore, as [Ulrich, 05] has pointed out, based on a structured sequence of learning objects and using different collections of tasks and methods that can be planned differently, this approach provides more enriched pedagogical descriptions than other course generation approaches, which are based on rules or provide access to learning materials via their metadata. Furthermore, it enables personalization (multiple roles can be involved and group or collaborative processes can be described) and more elaborate sequencing and interactions based on learner profiles (level B and C, which provide property manipulation), and therefore goes further than other related systems that consider providing the output as a sequence of learning objects in a similar structure to IMS-CP [Ulrich, 05].

Our proposal is also different from those that support IMS-LD authors in introducing corrective adaptations in the form of auxiliary specification files, which are constructed after an evaluation of the initial design on real users [Zarraonandia, 06]. Those approaches could cause additional problems in distance learning universities, where the monitoring process depends on tutors instead of the original authors. We are focussed on design issues and we argue that a critical problem is the specification of the workflow and corrections that could come up from the evaluation of the design on real users. At ADAPTAPlan, the author is requested to define the learning process in terms of objectives, learning activities, learning objects, educational services (i.e., forums, calendars, document storage spaces, etc.) and a set of conditions, initial requirements and restrictions in IMS-LD level B. Level B allows for modelling alternative learning itineraries, dynamic feedback, run-time tracking and collaborative learning [Bote-Lorenzo, 04].

ADAPTAPlan follows a step-wised approach combining user modelling, planning and machine learning techniques [Santos, 07b]. The process consists of 7 consecutive steps within a continuous loop intended to improve the adaptability and generalisability of learning routes (see figure 1):

1. The author provides the initial specification of course materials and modelling features (as described below)
2. From these requirements and the user model the planning engine generates a particularized learning route
3. The course learning route along with all the materials is loaded into the LMS
4. An extended version of the LD is provided with all the available resources so that if needed (step 5) replanning considers the course global picture
5. The planning engine provides a new plan when the original plan fails for that particular learner or the author has set up a stopping point (e.g., a general evaluation)
6. The planning engine guides the process with the new plan (step 5)
7. Every course execution is monitored and analysed in order to provide the required inputs for generating a general LD, which considers all the particular situations that took place. The new LD is expected to provide a better description of all the required particulars and can be further tested and extended with new course executions.

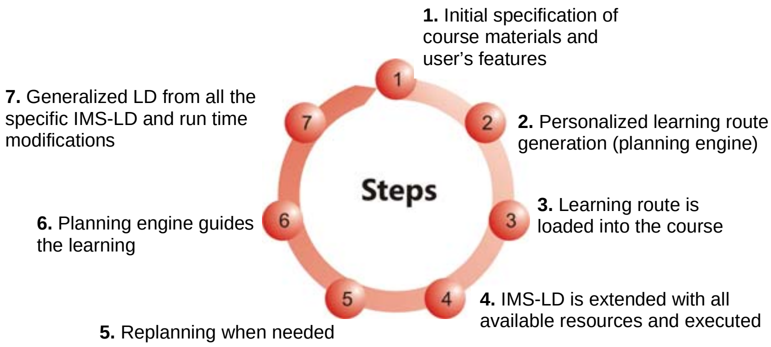

Figure 1: ADAPTAPlan step-wise process

Next, the specification requirements for courses are presented along with the work on a course from the ongoing education program at UNED (The National University for Distance Education in Spain).

3.1 Standards-based modelling of courses

Following the ADAPTAPlan approach, the author is requested to provide simple information about the course structure, pedagogy and restrictions that together with the user model can feed the planning engine to generate the personalized IMS-LD course suited to each learner. To deal with this approach, first we have identified the data to be filled in by the author for the planning engine. With these data an IMS-LD skeleton is built and stored as the course model. Next, the planning engine can use the user model (IMS-LIP and IMS Accessibility for LIP preferences) and the course model (IMS-LD skeleton) to generate the IMS-LD course design. These set of data is as follows:

- **Objectives**. The list of objectives to be worked on within the course is needed to link different design elements: contents, activities, resources, questionnaires.
- **Questionnaires**. To support the automatic creation of IMS-QTI questionnaires by the planning engine, a bank of questions has to be defined by the author. This task implies providing the following information for each question (item in IMS-QTI terminology): 1) text of the question, 2) possible answers, 3) correct answer, 4) score, 5) feedback for the right and wrong answers. Moreover, to dynamically create questionnaires from a large bank of items, each question has to be characterized by the following metadata: the objective, IMS-MD and Felder's features [Felder, 02] to identify for which type of users each item is more appropriate. Once the bank of items is defined, the name and questionnaire type (e.g. pre-knowledge, self-assessment, evaluation) have to be provided. Furthermore, the rules to dynamically build a questionnaire on the fly (according to the Selection and Ordering specification from QTI) have to be provided as well. This information comprises the number of questions to be included in a questionnaire and

how that number has to be selected from the bank of items. The later is provided in logical language (if-then clauses and logical operators).

- **Contents**. The course contents are external resources from the IMS-LD point of view. The course author has to provide the objectives where the contents are appropriate, and characterize them with Felder features and IMS-MD, as done with the questionnaire items above. Moreover, the location of the contents (local or external via URL) has also to be provided.
- **Services**. From the design point of view, services have to be independent of the LMS to be used at runtime. However, at design time the authors can provide the descriptions to allow their creation at publication time in any platform that supports that type of service. The idea is that different services are provided to perform different activities within the course. This information includes the title, the objectives (to be worked by the learners with that service) and the type of service, covering both traditional eLearning services such as forums and file folders, and collaborative ones such as the Logic Framework Approach [Santos, 04a, Santos, 04b].
- **Activities**. Here, the course author is only requested to provide the name, objective, wording, user roles involved and structural relations among activities (prerequisites, sequence and obligation). Specifying the structure for the activities and how they are related to course materials and services, the learner user model and even the interaction preferences is the most complicated task. However, if the course author has provided the previous information a planner can propose the structure for the activities part.

Finally, the initial course flow in IMS-LD is produced by the planning engine based on three data sources: (*i*) author information about the course structure, pedagogy and restrictions, (*ii*) characterized course contents and resources (i.e., teaching materials), and (*iii*) the expected results of the different questionnaires (tests on learning styles, cognitive modality and pre-knowledge test) and the evaluation of the modules performed by the learner in the previous modules' objectives (from the assessment questionnaires) (see figure 2). The generated IMS-LD formalizes the design of a learning process in a Unit of Learning (UoL) that is adapted to the individual learner's needs and can be executed in any standard-compliant LMS.

As can be seen in Figure 2, the specifications provided at design time are highlighted with thick arrows whereas those to be managed at run-time are shown in thin arrows. Moreover, since the novelty of this approach is based on the simplified specification of personalised learning scenarios we have not provided examples of how the different parts of an IMS-LD can be linked, which are illustrated elsewhere [Boticario, 07a].

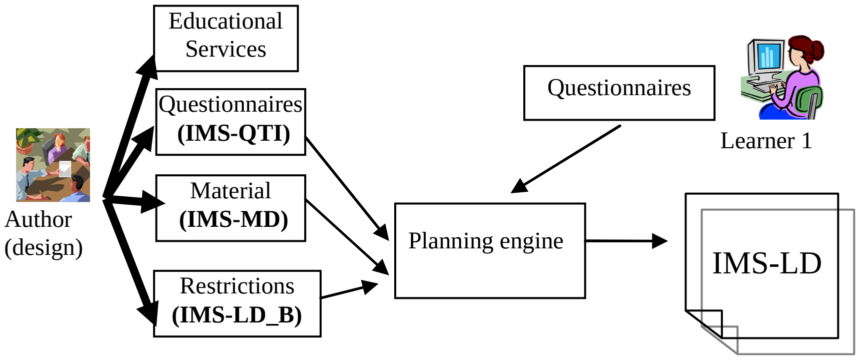

Figure 2: Initial course flow generation in ADAPTAPlan

3.2 User modelling features

From the initial experiences in different courses with the general approach previously described, in particular in an “Object Oriented Programming Course” (OOPC) and a course on “How to teach through the Internet” in the on-going education program at this university from year 2000 [Santos, 07c], we have come up with a more detailed specification of the user modelling features to be considered in the design phase. The current specification is intended to provide a wide-range of adaptation options to the planners, and consequently to the final IMS-LD.

The user modelling features that have been considered for designing the standards-based course are as follows [Baldiris, 08b]:

- **Learning Styles**. Keefe defines learning styles as the "composite of characteristic cognitive, affective, and physiological factors that serve as relatively stable indicators of how a learner perceives, interacts with, and responds to the learning environment” [Keefe, 79]. From the practical viewpoint the Felder’s Model, which focuses on the ways people take in and process information [Felder, 96], has been chosen. Felder’s selected dimensions are “processing” (with a range of values from active to reflective; active/reflective), “perception” (sensory/intuitive), “input” (visual/verbal), and “understanding” (sequential/global). The learning styles are used to divide learners into different clusters, depending on Felder’s dimensions, and those clusters are managed as fuzzy sets. The details are described elsewhere [Santos, 07c]. Basically, the idea is to identify strong preferences for one category (e.g., 9 or 11 value for the “verbal” cluster within the input dimension) so that the learning process could improve its effectiveness with instruction and materials adapted to those preferences.
- **Knowledge Level**. It is assumed that students master knowledge as they progress in the learning process. To manage this evolution the six levels of knowledge defined by Bloom’s taxonomy [Bloom, 56] (Knowledge, Understanding, Application, Analysis, Synthesis and Evaluation), in

increasing order of competency have been modelled. The knowledge level of a learner with respect to those levels can take one of the possible values: novice, average or expert.

- **Collaboration Level**. Collaboration indicators can be obtained from learners' active interactions in the course services, such as forums, shared files, comments, ratings, etc. As in the knowledge level feature, six competency levels in increasing order have been considered. The proposed levels (non_collaborative, communicative, participative, with_initiative, insightful and useful) come from previous experiences in collaborative settings [Santos, 04b] and each level has three alternative values, i.e., low, medium and high. According to this, a student that "makes comments and contributions that are considered by other learners" is assigned the high value for the "useful_learner" level.

Moreover, the device capabilities have to be taken into account to produce an adapted response for the user in the current context. The W3C Composite Capabilities/Preference Profiles (CC/PP)[2] specification is used to manage the device capabilities. The user preferences regarding access device are also stored in the user model (in terms of accessibility preferences). In this way, ADAPTAPlan system is able to adapt the contents to the user's access context in a dynamic way. The access device profile can be queried through an external CC/PP User Agent Profile repository (from the Open Mobile Alliance[3]) to provide some adaptations: i) changes on the platform interface to be properly displayed on the device, and ii) selection of some learning objects according to the CC/PP profile associated with the learner access device from those previously selected according to pedgagogical crieteria [Baldiris, 08a].

3.3 ADAPTAPlan in practice

To actually implement the ADAPTAPlan approach course designers should take into account the following steps, which resemble the methodology defined in aLFanet:

1. Developing course materials: materials are to be defined as a set of learning objects: this includes creation of IMS-QTI assessments and learning objects for the course contents.
2. Identifying course services: services within environments which coincides with e-learning resources, i.e., forums, news, calendar, document area, bookmarks, FAQs, comments, surveys, etc. The management of services that can be attached to a learning activity includes users' roles, access rights and services configuration. The definition of this type of services within an environment to be used at runtime is illustrated elsewhere [Boticario, 07a].
3. Metadata tagging for course materials: contents, activities, resources and questionnaires (see above) should be linked to objectives. Resources can be characterized with the following features from IMS-MD:

[2] W3C CC/PP specification: http://www.w3.org/Mobile/CCPP/
[3] OMA UaProf specification: http://www.openmobilealliance.org/tech/affiliates/wap/wap-248-uaprof-20011020-a.pdf

- Learning Resource Type: defining the didactic element allocated to the resource (exercise, simulation, table…)
- Format: setting the type of format to present the information (text, multimedia, graphic…)
- Density of Semantics: subjective measure of the descriptive character of the resource at hand. This points to the Felder's perception dimension so that the more descriptive is the resource the more appropriate for a sensitive learner; otherwise it better fits an intuitive one.
- Difficulty: identifying the expected knowledge level to deal with that specific resource.
- Interactivity level: describes the degree of interactivity associated with the resource.

Apart from the above IMS-MD features that are to be defined at design time, we have identified specific features from the users' interactions that can be used in runtime adaptations. In particular, comments, ratings and categories.

Moreover, the knowledge level is always associated with an objective within the course. It may be the global goal of the whole course, the partial goal of a chapter or section of the course, or at a lower level of granularity, the operational objective of an activity or task to be done during the course.

4. User profile modelling: defining the IMS-LD properties to model the different types of users provides the basic features that support adaptations, which are to be considered by the planning engine (see figure 2) to generate the personalized course workflow. The user profile is a combination of IMS-LIP and IMS-AccLIP that defines the profile of the user together with and IMS Reusable Definition of Competency or Educational Objective (IMS RDCEO). In more detail:
   - IMS-LIP: provides the general framework to define the general user characteristics, such as identification, goals, certification and licenses, acquired competencies, interests, etc. It can be linked to other specifications like IMS-RDCEO, which defines the user competencies. In particular, to drive adaptations we have considered Felder's Learning Styles, Knowledge Level based on Bloom's Taxonomy and the Collaborative Competency Level (see above).
   - IMS-AccLIP: an extension of IMS-LIP that considers the users preference regarding accessibility. IMS-AccLIP modifies the <*accessibility*> element in IMS-LIP, by removing the <*disability*> element and by addition of the <*AccessForAll*> element in this label. This new element considers information about how the materials are displayed, how the learner interacts with the system and the learner's preferences about the content.
   - IMS-RDCEO: a minimalist but extensible XML data model to define competencies or learning objectives. With this model it is possible to achieve a clear definition of competencies. It does not adjust to any particular curricular model and depending of the

author different characteristic elements of the competency can be considered. Each UoL in a LD refers to objectives that can be associated with an IMS-RDCEO competency definition. A learning object could be classified to contribute to a competency, referring from the <*classification*> element to a competency model, and relating IEEE LOM with IMS-RDCEO.

The learning style is something inherent to the learner, and the knowledge level is the knowledge acquired by a learner as regards a competency or instructional objective.

The collaborative competency level has to be promoted for each student in the context of a course. Actually, that level considers the participation inferred through the interaction data (obtained from forums, chat and other collaboration tools) and the access frequency of the user in a specific course [Baldiris, 08c].

In order to facilitate the planning engine task of providing resources to students according to their learning styles a table of correspondences, based on previous related work [Peña, 04; Karagiannidis y Sampson, 04], has been proposed. That table establishes links between every learning dimension (e.g., processing) and style (e.g., active), and the different resource types (e.g., experiments), which are valued amongst three possible alternative values: "very good", "good", and "indifferent". Thus, "Very good" represents a high value of a particular resource (e.g., simulation) for a given dimension (e.g., highly visual), whereas a middle value corresponds to "indifferent". Therefore, that table provides a clear specification of the types of resources for each learning style. For instance, an active (processing), intuitive (perception), global (understanding), and visual (input) learner can be provided by simulations, diagrams, figures, graphs, slides, and experiments as resource types. The details related to that table are described elsewhere [Baldiris, 07; Baldiris, 08b]. Moreover, examples of definitions that illustrate how to model the above elements in their corresponding specifications can be found in [Baldiris, 08b].

3.4 Dynamic-based modelling in ADAPTAPlan

As in aLFanet, ADAPTAPlan covers the full life cycle of learning (design, publication, use and auditing), which means that the specification of courses previously described represents just the design time issues but there are other features to support the run time of learning scenarios. While interacting with the system the learner is supported by a recommender system and the planning engine when needed. The latter takes control for replanning when the execution of the automatically generated course work flow (IMS-LD) reaches a blockage for whatever reason (e.g., the learner cannot meet a course milestone or get stacked in a particular learning activity) (see figure 1).

A multi-agent architecture is in charge of providing a continuous monitoring process of learner's interactions, learning some modelling features with machine learning techniques and providing recommendations to learners [Santos, 07c]. Actually, one of the lessons learned from the aLFanet project [Boticario, 07a] is that personalized learning flows do not suffice and learners tend to feel stress and lack of support when facing sequences of learning activities with their corresponding exercises and tests. To mitigate this problem and cope with unforeseen situations at design time we are applying a recommender system that is intended to provide the more appropriate recommendations amongst the available ones. The recommendation strategy decides internally the final recommendations from the pool of generated ones, taking into account the learning context provided by the IMS-LD and the user's interactions. To that end the recommender system follows a hybrid approach based on a multi-agent architecture which offers the flexibility for combining different recommendation techniques, collaborative filtering and content-based techniques [Santos, 08a]. Furthermore, several relevant factors have been detected to classify recommendation types (motivation, platform usage, collaboration, accessibility, learning styles and previous knowledge) so that they can be prioritized depending on the particular situation within the course (e.g., give priority to collaborative recommendations within a collaboration stage) [Santos, 08b]. The recommendations are provided through a new recommendation portlet that has been integrated in the dotLRN platform (see figure 3).

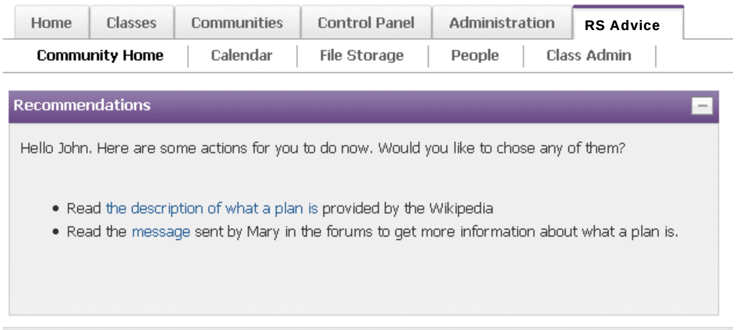

Figure 3: Recommendation portlet integrated in the dotLRN platform

The global system architecture to support dynamic features, called ADA+, consists of different intelligent agents that carry out diverse tasks. Some of these agents provide adaptation tasks using machine learning techniques in order to support 1) the user modelling (e.g. the Collaborative Competence Adapter) and 2) the adaptation process itself (e.g. the Learning Style Adapter). Other agents carry out integration tasks such as the Yellow Pages Agent and the Communicator agent. The Main Adapter is the principal adaptation process. It uses data provided by all the other agents and planning techniques to generate an IMS Learning Design adjusted to the user characteristics. The process for constructing learning routes and the details of the architecture are described elsewhere [Santos, 07c; Baldiris 08b; Baldiris 08c]. In this section we focus on describing how the adaptive features enrich the dynamically generated course design.

From the user model features described so far we have focussed on dynamically updating the following items:

- **Knowledge level**. The knowledge level is dynamically acquired through the analysis of learners' interactions with the learning objects and activities, and the evaluation results obtained from tests, questionnaires or other evaluation tasks.

- **Collaboration competency level**. The collaborative model is developed using database information about the learner's interaction in the collaborative tools. Data is pre-processed and the EM algorithm has been applied to generate users' clusters with similar collaboration behaviours [Baldiris, 08a]. Depending on the student's collaboration level the system can facilitate the generation of recommendations to encourage collaboration when needed.
- **Resources and learning styles**. The initial table of the types of resources more appropriate for each learning style (see above) can be adjusted according to the continuous monitoring process of learners' interactions and the machine learning tasks that have been defined. The process is described elsewhere [Baldiris, 08a] and consists in learning how each resource type addresses each learning style according to the given scale: very good, good or indifferent. To this, the system relies on the interaction traces that show the types of objects that have been chosen by a particular learning style cluster.

3.5 Ongoing experimentation activities

For the experimentation phase, we have created a course to be tested at UNED pilot site following the ADAPTAPlan approach, adapted from a course on "How to teach through the Internet" taught in the on-going education program at this university from year 2000. This course has already been designed following the aLFanet approach [Boticario, 07b]. Now, to comply with the ADAPTPlan proposal, we provided the above simplified information for the course. We took existing contents (point 1 from section 3.3), identified the required services, i.e. forums, FAQs, file storage area (point 2), tagged the resources and associated them with the corresponding learning objective (point 3), and selected the relevant user features to be considered (point 4).

Moreover, the ADAPTAPlan approach has also been applied to an "Object Oriented Programming Course" at Universidad de Gerona (another project pilot site) focussed on basic Object Oriented Programming topics such as object, class, inheritance, polymorphism, and encapsulation. The definitions of these concepts were done by experts in the subject. In the course, learning objects are organized by media type (e.g. sounds, graphics, text, and animations) in order to address the different learning styles of the student [Santos, 07c].

Actually, project partners focussed on planning issues have made progress in different areas to support the ADAPTAPlan approach, such as obtaining full HTN planning domain from learning objects repository [Castillo, 07a], developing a general planning formalism based on constraint programming and adapt it to an e-learning setting [Garrido, 07], including an expressive language for integrating existing protocols and a rich set of temporal constraints to deal with the specific domain of distance learning [Castillo, 07b], defining a new approach for case-based planning that is being applied to solve uncertainty factors when generating the plan [de la Rosa, 07].

4 Conclusions and future work

In this paper we have described design issues of a dynamic assistance approach for developing and modelling standards-based adaptive scenarios for current LMSs. In particular, we describe the problems we are tackling (from our past experience in the aLFanet project) and how we are relaxing the design work by automatically building the IMS-LD of the course from a simplified set of data required from the course authors (objectives, questionnaires, contents, services and activities). This approach is being carried out in the ADAPTAPlan project and has already been applied in an existing course from the on-going education program at UNED and in an "Object Oriented Programming Course" (OOPC) at Universidad de Gerona.

Our initial experiences have shown that course authors are much more predisposed to provide this set of information via a web-based interface rather than defining the whole IMS-LD design. In fact, with the existing contents from the course on 'How to teach through Internet' we have developed the corresponding IMS-LD applying both aLFanet and the ADATAPlan approaches. On the former, there were too many issues to focus on while doing the design (even applying the methodology provided) and it was very easy to get lost in the design process, increasing the time spent on it. However, the ADAPTAPlan approach helps to focus on the important elements. Even without applying the planning engine, it is easier for authors to come up with a more detailed design than following the aLFanet approach. What is more, it is technically possible to define a mapping between the IMS-LD structure and the planners' language defined in terms of properties, predicates and conditions. Bearing in mind the UNED pilot site, the next steps are to compare the output provided by different planners with the original IMS-LD design that we have built from the authors' set of data provided. Evaluations with more end-users are also planned for the third year of the ADAPTAPlan project.

It is important to note that the design of adaptive scenarios is still a complicated task. As shown in this paper, to support the automatic generation of a personalized IMS-LD a wide range of modelling features have to be provided. We expect that the development payoff comes from the reiterative application of the approach on courses with a significant number of students with varied profiles. This takes place in open courses (ongoing education program) at UNED, where the lifelong paradigm is actually implemented with students who are 30, 40 or 60 years of age or even older. This foresight has to be validated over the coming years since this is the first time the current open course "How to teach through the Internet" has been modelled according to the ADAPTAPlan approach.

Furthermore, the reusability and flexibility of the approach is based on the usage of standards-based educational scenarios and open LMSs to describe and manage all the required information, and on a multi-agent architecture that interoperates with the LMSs by means of web services. This architecture offers the flexibility for combining different recommendation techniques, including collaborative filtering and content-based techniques, as it is described elsewhere [Baldiris, 08c].

Finally, we claim that the combination of techniques that are being applied in ADAPTAPlan have a particular interest since they can be considered an instance of a general type of problem focussed on providing personal assistance to users in terms of combining planning and user modelling techniques, as it is shown in a system for planning tourist visits [Castillo, 08] .

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